

TITLE OF THE INVENTION
SEMICONDUCTOR MEMORY INCLUDING STATIC RANDOM ACCESS
MEMORY FORMED OF FINFET

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is based upon and claims the
benefit of priority from prior Japanese Patent
Application No. 2003-375851, filed November 5, 2003,
the entire contents of which are incorporated herein by
reference.

10 BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a semiconductor memory,
in particular, a static random access memory
(hereinafter referred to as "SRAM") formed of FinFETs.

15 2. Description of the Related Art

Generally, when a memory cell for an SRAM
(hereinafter referred to as "SRAM cell") is designed, a
good data-holding property is secured by setting the
device resistance of a transfer gate transistor to a
20 value higher than that of the device resistance of a
drive transistor. Specifically, this is achieved by
providing a driver transistor having a shorter channel
length (L) and a wider channel width (W) than those of
the transfer gate transistor.

25 Recently, as a transistor of a new structure,
Fin typed Double-Gate MIS field effect transistor
(hereinafter referred to as "FinFET") having a

three-dimensional structure receive attention. The FinFET has the following structure.

A single-crystal silicon layer of an SOI (silicon on insulator) substrate is processed into rectangular
5 pieces to form projecting regions (hereinafter referred to as "fin layer") being semiconductor regions. A gate electrode is crossed over the fin layer, and thereby the fin layer is used as a channel (for example, please refer to Jpn. Pat. Appln. KOKAI Pub. No. 2-263473).

10 SRAMs formed of the FinFETs have been proposed (for example, please refer to E.J. Nowak et al., "A Functional FinFET-DGCMOS SRAM Cell", IEDM 2002 Technical Digest, pp 411-414). FIG. 1 is a layout diagram illustrating an SRAM cell formed of FinFETs.
15 FIG. 2 is a layout diagram illustrating a cell array of an SRAM, in which the SRAM cells are arranged. As shown in FIG. 1, an SRAM cell 100 is a 6-transistor SRAM cell, which is formed of six transistors. Specifically, the SRAM cell 100 comprises two drive
20 transistors 101 and 102, two transfer gate transistors 103 and 104, and two load transistors 105 and 106.

However, since the channel width (W) of a FinFET depends on the height of the fin layers, it is difficult from the viewpoint of the process to allow
25 the transistors to have different channel widths (W). Therefore, there is a problem that it is difficult to obtain a good data-holding property with an SRAM formed

of FinFETs.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention,
a semiconductor memory of the present invention
5 comprises: a first and a second field effect
transistors having a first line as gates, one ends of
current paths of the first and second field effect
transistors being connected to a reference electrode
supplied with a reference potential; a third and a
10 fourth field effect transistors having a second line as
gates, one ends of current paths of the third and
fourth field effect transistors being connected to the
reference electrode; a fifth field effect transistor
having a first word line as a gate, one end of a
15 current path of the fifth field effect transistor being
connected to the other ends of the current paths of the
first and second field effect transistors; and a sixth
field effect transistor having a second word line as a
gate, one end of a current path of the sixth field
20 effect transistor being connected to the other ends of
the current paths of the third and fourth field effect
transistors.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a layout diagram illustrating a
25 structure of a conventional SRAM cell formed of
FinFETs.

FIG. 2 is a layout diagram illustrating a cell

array obtained by integrating the conventional SRAM cells each formed of FinFETs.

FIG. 3 is a layout diagram illustrating a structure of an SRAM cell according to a first embodiment of the present invention.

FIG. 4 is a circuit diagram of the SRAM cell of the first embodiment.

FIG. 5 is a layout diagram of a cell array obtained by integrating the SRAM cells of the first embodiment.

FIG. 6 is a layout diagram illustrating a structure of an SRAM cell according to a second embodiment of the present invention.

FIG. 7 is a layout diagram illustrating a cell array obtained by integrating the SRAM cells of the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will now be explained below with reference to drawings. In explanation, like reference numerals denote like constituent elements through the drawings.

First Embodiment

First, a semiconductor memory including an SRAM according to a first embodiment of the present invention is explained. FIG. 3 is a layout diagram illustrating a structure of an SRAM cell according to the first embodiment. FIG. 4 is a circuit diagram of

the SRAM cell.

As shown in FIG. 3, in an SRAM cell 11, arranged are four drive transistors DR1, DR2, DR3 and DR4, two transfer gate transistors TR1 and TR2, and two load
5 transistors LO1 and LO2. The SRAM cell 11 is a memory cell in an SRAM, and is a basic structure, which stores data of 1 bit.

First, the following is a detailed structure of the drive transistors DR1 to DR4. As shown in FIG. 3,
10 active regions (element regions) A1 and A2 are formed in parallel and apart from each other. The active regions A1 and A2 are formed of projecting silicon layers (fin layers), and all the other active regions described later are formed of fin layers. Above the
15 active regions A1 and A2, gate electrodes G1 and G2 are formed apart from each other and in parallel, such that each of the gate electrodes is orthogonal to the active regions A1 and A2. A channel region is formed in each portion of the active regions A1 and A2, which is
20 located under the gate electrodes G1 and G2. A source and a drain are formed in portions of the active regions A1 and A2 to hold each channel region therebetween.

By such a structure, the drive transistor DR1 is
25 formed at an intersection point of the active region A1 and the gate electrode G1, and the drive transistor DR3 is formed at an intersection point of the active region

A1 and the gate electrode G2. In the same manner,
the drive transistor DR2 is formed at an intersection
point of the active region A2 and the gate electrode
G1, and the drive transistor DR4 is formed at an
5 intersection point of the active region A2 and the gate
electrode G2.

An active region A3 which is electrically
connected to the active regions A1 and A2 is formed to
be orthogonal to the active regions A1 and A2. A
10 contact C1 is formed on one end of the active region
A3, and a reference potential Vss is supplied to the
contact C1. Further, a contact C2 is formed on one
ends of the active regions A1 and A2, and a contact C3
is formed on the other ends of the active regions A1
15 and A2.

Next, a detailed structure of the transfer gate
transistors TR1 and TR2 are described below. As shown
in FIG. 3, active regions A4 and A5 are formed such
that each of them is perpendicular to the active
regions A1 and A2. Above the active region A4, a gate
20 electrode G3 is formed to be perpendicular to the
active region A4. Above the active region A5, a gate
electrode G4 is formed to be perpendicular to the
active region A5. A channel region is formed in each
25 portion of the active regions under the gate electrodes
G3 and G4. In each of the active regions, a source and
a drain are formed to hold each channel region

therebetween.

By such a structure, the transfer gate transistor TR1 is formed at an intersection point of the active region A4 and the gate electrode G3, and the transfer gate transistor TR2 is formed at an intersection point of the active region A5 and the gate electrode G4.

One end of the active region A4 is connected to the contact C2, and a contact C4 is formed on the other end of the active region A4. The contact C4 is connected with a bit line BL. One end of the active region A5 is connected to the contact C3, and a contact C5 is formed on the other end of the active region A5. The contact C5 is connected with the bit line BL. Further, a contact C6 is formed on one end of the gate electrode G3, and a contact C7 is formed on one end of the gate electrode G4. The contacts C6 and C7 are connected to respective word lines WL.

Next, the detailed structure of the load transistors L01 and L02 is described below. As shown in FIG. 3, an active region A6 is formed in parallel with the active regions A1 and A2. The gate electrodes G1 and G2 are extended and disposed above the active region A6 such that the gate electrodes G1 and G2 are perpendicular to the active region A6. A channel region is formed in each portion of the active region A6 under the gate electrodes G1 and G2. A source and a drain are formed in portions of the active region 6 to

hold each channel region therebetween.

By such a structure, the load transistor L01 is formed at an intersection point between the active region A6 and the gate electrode G1, and the load transistor L02 is formed at an intersection point between the active region A6 and the gate electrode G2.

A contact C8 is formed on one end of the active region A6, and a contact C9 is formed on the other end of the active region A6. An active region A7 which is electrically connected to the active region A6 is formed to be perpendicular to the active region A6. A contact C10 is formed on one end of the active region A7, and a power supply voltage Vdd is supplied to the contact C10. Further, contacts C11 and C12 are formed in the center or around of the gate electrodes G1 and G2, respectively.

A line 12 shown by a broken line in FIG. 3 connects the contacts C2, C8 and C12. A line 13 connects the contacts C3, C9 and C11.

The following is a detailed explanation of the connection relationship in the SRAM cell.

The drive transistors DR1 and DR2 have a first gate line in common as their gates, and one ends of their current paths are connected to a reference electrode supplied with the reference potential Vss. The drive transistors DR3 and DR4 have a second gate line in common as their gates, and one ends of their

current paths are connected to the reference electrode supplied with the reference potential V_{ss} .

The transfer gate transistor TR1 has a first word line as gate, and one end of a current path thereof is
5 connected to the other ends of the current paths of drive transistors DR1 and DR2. The transfer gate transistor TR2 has a second word line as a gate, and one end of a current path thereof is connected to the other ends of the current paths of the drive
10 transistors DR3 and DR4.

More specifically, the current paths of the drive transistors DR1 and DR2 are connected in parallel between the one end of the current path of the transfer gate transistor TR1 and the reference electrode. The
15 current paths of the drive transistors DR3 and DR4 are connected between the one end of the current path of the transfer gate transistor TR2 and the reference electrode.

The load transistor L01 has the first gate line as
20 a gate, and one end of its current path is connected to a power supply electrode supplied with the power supply voltage. The load transistor L02 has the second gate line as a gate, and one end of its current path is connected to the power supply electrode supplied with
25 the power supply voltage.

The other ends of the current paths of the drive transistors DR1 and DR2 are connected to the other end

of the current path of the load transistor LO1.
The other ends of the current paths of the drive
transistors DR3 and DR4 are connected to the other end
of the current path of the load transistor LO2..

5 Further, the gates of the drive transistors DR1
and DR2 and the load transistor LO1 are connected to
the other ends of the current paths of the drive
transistors DR3 and DR4. The gates of the drive
transistors DR3 and DR4 and the load transistor LO2 are
10 connected to the other end of the current path of the
load transistor LO1.

The SRAM cell according to the first embodiment
has a structure in which two drive transistors in
parallel are used instead of each of the drive
15 transistors in the 6-transistor SRAM cell shown in
FIG. 1. In a FinFET, since a fin layer (element
region) formed of a projecting silicon layer is formed
with a fixed height, the channel width thereof is
fixed. In the embodiment, two FinFETs are connected in
20 parallel, and thereby the effective channel width
thereof is twice that of the conventional drive
transistor formed of one FinFET with a fixed channel
width. This reduces the total element resistance of
the two drive transistors in the embodiment to 1/2 that
25 of the transfer gate transistor having one transistor.
As a result, the β ratio is 2, and it is possible to
obtain a good data-holding property. In the

embodiment, the ratio of the number of the drive transistors to the number of the transfer gate transistors is 2, that is, two drive transistors are arranged for each transfer gate transistor. However, 5 the ratio is not limited to 2, but may be another number larger than 2. For example, the ratio may be 3 or 4.

FIG. 5 is a layout diagram illustrating a structure of a cell array obtained by integrating the 10 SRAM cells. The cell array of the SRAM is formed by arranging a plurality of the SRAM cells, one of which is shown in FIG. 3, in rows and columns as shown in FIG. 5.

Second Embodiment

15 Next, a semiconductor memory including an SRAM according to a second embodiment of the present invention will be described. The same constituent elements as those in the structure of the first embodiment are denoted by the same respective reference 20 numerals, and their explanations are omitted. Only different constituent elements are explained below.

FIG. 6 is a layout diagram illustrating the structure of an SRAM cell according to the second embodiment. An SRAM cell 21 has a structure in which 25 eight transistors are arranged symmetrically with respect to the central point CN of the SRAM cell 21. The circuit diagram of the SRAM cell 21 is the same as

that of the first embodiment shown in FIG. 4.

In the SRAM cell 21, provided are four transistors, that is, drive transistors DR1 and DR2, a transfer gate transistor TR1, and a load transistor L01. Further, the SRAM cell 21 has drive transistors DR3 and DR4, a transfer gate transistor TR2, and a load transistor L02. The drive transistors DR1 and DR3 are arranged symmetrically with respect to the central point CN of the SRAM cell 21. The drive transistors DR2 and DR4, the transfer gate transistors TR1 and TR2, and the load transistors L01 and L02 are also arranged symmetrically in a like manner.

First, the following is the detailed structure of the drive transistors DR1 and DR2. As shown in FIG. 6, active regions A11 and A12 are formed in parallel, apart from each other. Each of the active regions A11 and A12 is formed of a fin layer, and all the other active regions described below are formed of fin layers. Above the active regions A11 and A12, a gate electrode G11 is formed to be crossed over the active regions A11 and A12. A channel region is formed in each portion of the active regions A11 and A12 located under the gate electrode G11. A source and a drain are formed in portions of the active regions A11 and A12 to hold each channel region therebetween.

By such a structure, the drive transistor DR1 is formed at an intersection point between the active

region A11 and the gate electrode G11, and the drive transistor DR2 is formed at an intersection point between the active region A12 and the gate electrode G11.

5 A contact C21 formed on one ends of the active regions A11 and A12. A contact 22 is formed to be located in the central portion of the active region A11 and on the other end of the active region A12. Further, the contact C21 is supplied with a reference
10 voltage Vss.

 Next, the following is a detailed structure of the transfer gate transistor TR1. As shown in FIG. 6, the active region A11 is extended. Above the extended active region A11, a gate electrode G12 is formed
15 orthogonal to the active region A11. A channel region is formed in a portion of the active region A11 located under the gate electrode G12, and a source and a drain which hold the channel region therebetween are formed in portions of the active region A11.

20 By such a structure, the transfer gate transistor TR1 is formed at an intersection point between the active region A11 and the gate electrode G12.

 A contact C23 is formed on the other end of the active region A11. A bit line /BL is connected with
25 the contact C23. Further, a contact C24 is formed on one end of the gate electrode G12. The contact C24 is connected with a word line WL.

Next, the following is a detailed structure of the load transistor L01. As shown in FIG. 6, an active region A13 is formed in parallel with the active regions A11 and A12. Above the active region A13, the gate electrode G11 is extended and arranged orthogonal to the active region A13. A channel region is formed in a portion of the active region A13 under the gate electrode G11. A source and a drain which hold the channel region therebetween are formed in the active region A13.

By such a structure, the load transistor L01 is formed at an intersection point between the active region A13 and the gate electrode G11.

A contact 25 is formed on one end of the active region A13, and supplied with a power supply voltage Vdd. Further, a contact C26 is formed on the other end of the active region A13.

Further, in the SRAM cell 21, the drive transistors DR3 and DR4, the transfer gate transistor TR2, and the load transistor L02 are arranged symmetrical to the drive transistors DR1 and DR2, transfer gate transistor TR1, and the load transistor L01, respectively, with respect to the central point CN of the SRAM cell 21. A line 22 shown by a broken line in FIG. 6 connects the contacts C22 and C26.

In the SRAM cell of the second embodiment configured as described above, two FinFETs connected in

series are used instead of one conventional drive transistor, in the same manner as in the first embodiment. This increases the effective channel width of the embodiment twice that of the conventional drive transistor, and thereby the total element resistance of the two drive transistors can be reduced to 1/2 that of the transfer gate transistor formed of one transistor. As a result, the β ratio is 2, and a good data-holding property can be obtained. Also in this embodiment, the ratio of the number of the drive transistors to the number of the transfer gate transistors is not limited to 2, but may be other numbers exceeding 2. For example, the ratio may be 3 or 4. Further, the SRAM cell of the second embodiment is suitable for high integration, since it can be formed with an area smaller than that of the SRAM cell of the first embodiment.

FIG. 7 is a layout diagram illustrating a structure of a cell array obtained by integrating the SRAM cells. The cell array of the SRAM is formed by a plurality of the SRAM cells, one of which is shown in FIG. 6, arranged in rows and columns as shown in FIG. 7.

According to the embodiments of the present invention, it is possible to provide a semiconductor memory formed of FinFETs and having a good data-holding property.

Further, the above embodiments can not only be carried out singly, but also in combination. Further, each of the embodiments includes inventions of various phases, and it is possible to extract inventions of various phases by combining a plurality of constituent elements disclosed in the embodiments according to circumstances.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.